MIL-STD-188-110C Appendix D
Digital Voice Data Rate Performance

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Agenda

- History of Legacy HF Data Modem Waveforms
- MIL-STD-188-110C Appendix D Data Waveform Suite
- HF Digital Voice Overview
- MIL-STD-110C Appendix D 3 kHz Digital Voice Rates
- 110C versus 110B Digital Voice Rate Performance
- Digital Voice Quality in Severe HF Conditions
- 110C Appendix D 3 kHz Mid-Data Rate Sidebar
- Summary
History of Legacy HF Data Modem Waveforms

- Legacy 3 kHz HF band autobaud waveforms
  - MIL-STD-188-110B: Coded data rates from 75 bps through 2400 bps (3 kHz band)
  - MIL-STD-188-110B App C: Coded data rates from 3200 bps through 9600 bps (3 kHz band)
  - MIL-STD-188-110B App F: Independent sideband (two 3 kHz sidebands or frequencies): Coded data rates from 9600 bps through 19,200 bps
Wideband HF (WBHF) Data Waveform Overview

- MIL-STD-188-110C Appendix D Data Waveform Suite
  - Comprised of eight data waveforms for eight HF bandwidths, 3 kHz through 24 kHz in 3 kHz bandwidth increments providing data rates ranging from 75 bps for the lowest 3 kHz rate to 120 kbps for the highest 24 kHz rate.
  - All eight waveforms fully autobaud across the 12 to 14 data rates and four interleaver options available to each waveform
    - Interleaver lengths: 0.12, 0.48, 1.92, and 7.68 seconds
  - Configurable constraint length coding, k=7 and k=9
110C Appendix D 3 kHz Waveform Characteristics

- New MIL-STD-188-110C Appendix D, 3 kHz band
  - Coded data rates from 75 bps through 9600 bps
  - Lightly coded data rates 12,000 and 16,000 bps
  - Four interleaver options: 0.12, 0.48, 1.92, and 7.68 seconds
  - Data rates, interleaver, and constraint lengths fully autobaud
<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Modulation Type</th>
<th>Code Rate</th>
<th>Frame Data Symbols</th>
<th>Frame Known Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>Walsh</td>
<td>1/2</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>150</td>
<td>BPSK</td>
<td>1/8</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>300</td>
<td>BPSK</td>
<td>1/4</td>
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<tr>
<td>600</td>
<td>BPSK</td>
<td>1/3</td>
<td>96</td>
<td>32</td>
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<tr>
<td>1200</td>
<td>BPSK</td>
<td>2/3</td>
<td>96</td>
<td>32</td>
</tr>
<tr>
<td>1600</td>
<td>BPSK</td>
<td>3/4</td>
<td>256</td>
<td>32</td>
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<td>2400</td>
<td>QPSK</td>
<td>9/16</td>
<td>256</td>
<td>32</td>
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<tr>
<td>3200</td>
<td>QPSK</td>
<td>3/4</td>
<td>256</td>
<td>32</td>
</tr>
<tr>
<td>4800</td>
<td>8PSK</td>
<td>3/4</td>
<td>256</td>
<td>32</td>
</tr>
<tr>
<td>6400</td>
<td>16QAM</td>
<td>3/4</td>
<td>256</td>
<td>32</td>
</tr>
<tr>
<td>8000</td>
<td>32QAM</td>
<td>3/4</td>
<td>256</td>
<td>32</td>
</tr>
<tr>
<td>9600</td>
<td>64QAM</td>
<td>3/4</td>
<td>256</td>
<td>32</td>
</tr>
<tr>
<td>12000</td>
<td>64QAM</td>
<td>8/9</td>
<td>360</td>
<td>24</td>
</tr>
<tr>
<td>16000</td>
<td>256QAM</td>
<td>8/9</td>
<td>360</td>
<td>24</td>
</tr>
</tbody>
</table>
HF Digital Voice Overview

• Digitized voice bits modulated using an HF waveform for over-the-air transport

• Higher the digitized voice rates, the better the voice quality

• Some Common digital voice vocoders used at HF:
  – LPC-10: 2400 bps
  – MELPe (STANAG 4591): 600, 1200, and 2400 bps

• Example HF waveforms supporting digital voice rates:
  – MIL-STD-188-110B (600, 1200, 2400 bps)
  – STANAG 4285 (600, 1200, 2400 bps)
  – MIL-STD-188-110B Appendix B (39-tone; 600, 1200, 2400 bps)
MIL-STD-110C Appendix D 3 kHz Digital Voice Rates

- MIL-STD-110C 3 kHz waveform data rates include digital voice data rates with following characteristics:
  - 2400 bps data rate
    - 110C utilizes QPSK with a code rate of 9/16
    - 110B utilizes 8-ary PSK with a code rate of 1/2
  - 1200 bps data rate
    - 110C utilizes BPSK with a code rate of 2/3
    - 110B utilizes QPSK with a code rate of 1/2
  - 600 bps data rate
    - 110C utilizes BPSK with a code rate of 1/3
    - 110B utilizes BPSK with a code rate of 1/2
  - 110C features a configurable constraint length parameter for two options: standard constraint length 7 and more robust constraint length 9 coding (requiring additional processing resources)
  - 110C features 0.12 and 0.48 second interleaver lengths versus the 0.6 second interleaver length of 110B for the digital voice data rates
110C versus 110B Digital Voice Rate Performance

- The following slides depict the Bit-Error-Rate (BER) curves for the digital voice data rates: 600, 1200, and 2400 bps
- At 2400 bps, 110C performance approximately 5 dB better than 110B
- At 1200 bps, 110C about 0.5 dB better than 110B
- At 600 bps, 110C about 3 dB better than the 110B

- **Note:** The 110B BER performance (black curve) shown in the following slides is an average of three different implementations
110C Digital Voice Performance (CCIR Poor)

- CCIR Poor channel simulation parameters:
  - Two equal power paths
  - Delay spread between paths is two milliseconds
  - Doppler spread on each path is 1 Hz
  - Simulated STANAG 4203 radio filters were not used
3 kHz WBHF Waveform CCIR Poor BER Performance 2400 bps

- 2400 BER 110C K=7
- 2400 BER 110C K=9
- 2400 BER 110B (avg of 3)
3 kHz WBHF Waveform CCIR Poor BER Performance 1200 bps

![Graph showing BER performance vs. SNR in 3 kHz.](image)

- Blue line: 1200 BER 110C K=7
- Red line: 1200 BER 110C K=9
- Black line: 1200 BER 110E (avg of 3)
3 kHz WBHF Waveform CCIR Poor BER Performance 600 bps

- 600 BER 110C K=7
- 600 BER 110C K=9
- 600 BER 110B (avg of 3)

SNR vs BER graph showing performance at different SNR levels.
110C versus 110B bps AWGN BER Performance

- AWGN channel simulation parameters:
  - One power path
  - No Doppler spread
  - Simulated STANAG 4203 radio filters were not used
3 kHz WBHF AWGN BER for Digital Voice Rates, 110B versus 110C App D: 2400 bps

BER

SNR in 3 kHz

1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
2 3 4 5 6 7 8 9 10 11 12 13 14

110C 2400 BER K7
110C 2400 BER K9
110B 2400 BER (K7)
3 kHz WBHF AWGN BER for Digital Voice Rates, 110B versus 110C App D: 1200 bps

SNR in 3 kHz

BER

1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08

110C 1200 BER K7
110C 1200 BER K9
110B 1200 BER (K7)
3 kHz WBHF AWGN BER for Digital Voice Rates, 110B versus 110C App D: 600 bps

- 110C 600 BER K=7
- 110C 600 BER K=9
- 110B 600 BER (K=7)

BER vs SNR in 3 kHz

Rockwell Collins, Inc.
110C Appendix D 3 kHz Waveform Provides Robust Digital Voice Transport in Severe HF Conditions

**Analog Voice Examples**

- Analog Voice at 0 dB SNR
- Analog Voice at 2 dB SNR
- Analog Voice at 5 dB SNR
- Source Analog Voice
110C Appendix D 3 kHz Waveform Provides Robust Digital Voice Transport in Severe HF Conditions

Digital Voice Examples

- 2400 bps MELPe Reference
- 2400 MELPe Digital Voice with 110B Single Tone at 5 dB SNR
- 2400 MELPe Digital Voice with 110C App D at 5 dB SNR
- 2400 MELPe Digital Voice with 110C App D at 2 dB SNR
- 2400 MELPe Digital Voice with 110C App D at 1 dB SNR
- 2400 MELPe Digital Voice with 110C App D at 0 dB SNR
- 1200 MELPe Digital Voice with 110C App D at 1 dB SNR
110C Appendix D 3 kHz Mid-Data Rate Sidebar

- MIL-STD-188-110C Appendix D adjacent mid-range data rate performance is more orderly than legacy STANAG 4539 or 110B modes for adaptive data rate applications
  - STANAG 4539/110B autobaud implementations combine multiple waveforms providing data rate coverage from 75 bps to 9600 bps without receiver mode changes
  - Significant weakness in the 1200, 2400, and 3200 bps progression due to the superior performance of the 3200 bps rate (QPSK) over the 2400 bps rate (8PSK)
# 110C App D 3 kHz Mid-Data Rate Spec Range (CCIR Poor)

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>Modulation Type</th>
<th>1E-5 BER SNR Range for Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1200 bps</td>
<td>BPSK (Rate 2/3)</td>
<td>9 dB to 10 dB</td>
</tr>
<tr>
<td>1600 bps</td>
<td>BPSK (Rate 3/4)</td>
<td>9 dB to 11 dB</td>
</tr>
<tr>
<td>2400 bps</td>
<td>QPSK (Rate 9/16)</td>
<td>10 dB to 12 dB</td>
</tr>
<tr>
<td>3200 bps</td>
<td>QPSK (Rate 3/4)</td>
<td>14 dB to 15 dB</td>
</tr>
</tbody>
</table>
110C App D 3 kHz Digital Voice Data Rate Summary

- Significant Performance Improvement over MIL-STD-188-110B Single Tone

<table>
<thead>
<tr>
<th>Data Rate</th>
<th>SNR Improvement (AWGN)</th>
<th>SNR Improvement (CCIR Poor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2400 bps</td>
<td>5 dB</td>
<td>5 dB</td>
</tr>
<tr>
<td>1200 bps</td>
<td>2 dB</td>
<td>0.5 dB</td>
</tr>
<tr>
<td>600 bps</td>
<td>2 dB</td>
<td>3 dB</td>
</tr>
</tbody>
</table>

- 110C App D provides a reliable transport for Digital Voice in extreme HF Conditions
- Constraint length 9 convolutional coding results in up to a 1 dB performance gain in AWGN channel simulations for digital voice data rates
- Adjacent data rate performance is more orderly than legacy STANAG 4539
3 kHz 110C App D Digital Voice Data Rate Summary

- Questions?